

DEPTH DISTRIBUTION OF ROOTS OF SOME PERENNIAL PLANTS IN THE NEVADA TEST SITE AREA OF THE NORTHERN MOJAVE DESERT

A. Wallace¹, E. M. Romney¹, and J. W. Cha¹

ABSTRACT.— The root systems of 48 perennial plants, representing nine species from the Rock Valley area within the northern Mojave Desert, were excavated by 10 cm depth increments to determine, by depth of soil, the distribution of roots larger than about ½ mm diameter. The depth of the root zone of all species was relatively shallow and obviously limited by depth of penetration of precipitation (about 10 cm mean annual rainfall).

There were species differences, however, in distribution of roots. Even though a sizeable proportion of the root systems was in the first 10 cm of soil, this portion consisted largely of multiple woody tap roots with relatively few small roots. In all cases except one (*Krameria parvifolia* Benth.), more small roots were in the second 10 cm than in the first. From 50 to more than 80 percent of the total root systems were in the first 20 cm. In most cases the majority of small roots was found between 10 and 30 cm in depth. Very fine roots were sampled separately by depth and zone without regard for species because they could not be differentiated by species. Relative depth distribution of very fine roots at Rock Valley for 0–10, 10–20, and 20–30 cm, was about 17, 42, and 41 percent, respectively. The total for the first 20 cm was 59 percent. On a 22 April date, there were 225 kg/ha roots from winter annuals in the Rock Valley area; 19 percent of them were in the first 5 cm of soil in contrast to 8 percent in 10 cm of soil for perennials. On Pahute Mesa located in the southern Great Basin desert area of the Nevada Test Site in *Artemisia tridentata* Nutt. var. *tridentata*, 8 percent of the roots was in the first 5 cm, indicating more shallow rooting compared with the northern Mojave Desert.

Any understanding of the role of soil on desert ecosystems requires that the distribution of plant roots in soil profiles be known. This investigation was to obtain some of this information. Rooting habits of desert plants in the western United States have been studied with conclusions that they generally are not deep-rooted unless they are in places where rain water accumulates (Cannon 1870, Dittmer 1964, Markle 1917, Waterman 1923). These workers recognized that depth of rooting was often limited by caliche layers near the soil surface or by unfavorable soil chemistry or soil physics. None of them, however, reported quantitative information on the amounts of roots at different depths. Consequently, the distribution with depth of roots of several major perennial plants in the Rock Valley area of the northern Mojave Desert was obtained.

MATERIALS AND METHODS

Root systems of 48 individual plants representing nine species were excavated during

the spring and summer of 1972. The species, with numbers of individuals sampled, were: *Atriplex canescens* (Pursh) Nutt. (four-wing salt bush) (6), *Acamptopappus shockleyi* Gray (3), *Atriplex confertifolia* (Torr. & Frem.) Wats. (shadscale) (7), *Larrea tridentata* (Sesse & Moc. ex DC.) Cov. (creosote bush) (3), *Ephedra nevadensis* Wats. (Mormon tea) (7), *Lycium andersonii* A. Gray (wolfberry or desert thorn) (5), *Lycium pallidum* Miers (wolfberry or desert thorn) (6), *Krameria parvifolia* Benth. (3), *Ambrosia dumosa* (A. Gray) Payne (burro bush) (8). The numbers in parentheses refer to the number of plants excavated for each species. Nomenclature of the species follows Beatley (1976). These collections were made in connection with other studies that involve the shoot:root relationship of perennial desert plants in the field. The excavations were made by hand shovel and roots were separated by 10 cm depth increments.

The soil was carefully excavated for each plant and often 1 to 3 m³ of soil was removed. The soil was not screened to remove

¹Laboratory of Nuclear Medicine and Radiation Biology, University of California, Los Angeles, California 90024.

TABLE 1. Distribution by depth of roots from nine perennial plant species collected from Rock Valley to northern Mojave Desert (values are percent of total root system).

Depth cm	<i>A. shockleyi</i> (3)	<i>L. tridentata</i> (3)	<i>L. andersonii</i> (5)	<i>L. pallidum</i> (6)
Large roots				
0-10	45.7 ± 9.4	24.4 ± 0.8	25.9 ± 5.4	27.5 ± 4.5
10-20	25.3 ± 7.5	25.4 ± 1.0	15.5 ± 3.6	28.3 ± 4.8
20-30	5.2 ± 2.9	12.6 ± 1.9	15.1 ± 2.6	9.8 ± 2.0
30-40	0.8 ± 0.8	7.0 ± 1.6	9.2 ± 2.0	5.4 ± 0.4
40-50	0.0	3.1 ± 2.2	8.7 ± 3.8	3.5 ± 1.6
Over 50	0.0	0.0	0.0	0.0
Small roots				
0-10	5.9 ± 1.6	2.1 ± 0.7	2.2 ± 0.8	2.9 ± 1.1
10-20	8.5 ± 6.1	8.3 ± 2.6	8.2 ± 2.0	10.5 ± 3.4
20-30	7.1 ± 6.4	7.2 ± 1.7	7.3 ± 1.7	6.5 ± 2.5
30-40	1.5 ± 1.5	4.1 ± 1.5	4.6 ± 1.2	3.2 ± 0.9
40-50	0.0	2.9 ± 1.8	3.1 ± 0.7	2.6 ± 1.1
Over 50	0.0	0.0	0.0	0.0
Percent of Total	23.0	24.6	25.5	25.7

± is standard error of mean.

Numbers in parentheses under species are number of plants in sample.

fine roots (smaller than about $\frac{1}{2}$ mm) but sufficient soil was removed with each plant to obtain the large majority of the root system. We estimate that no more than 30 percent of the root system was missed and this mostly because of very fine roots that were handled separately. Plants were selected to give minimum interference to adjoining shrubs. The fine-root problem was handled as follows: In April and September 1976 at the Nevada Test Site, a series of soil samples 1 liter in volume each were collected on the patterns for samples used by Bamberg et al. (1974). The purpose was to estimate the fine roots and organic debris floated with conventional salts. Only a portion (35 percent) of the organic debris was considered as roots because that was the maximum possible according to our ^{14}C labeling techniques (Wallace et al. 1980, this volume).

RESULTS AND DISCUSSION

The mean weight of root systems of field plants, together with percentage distribution by depth with standard errors for each increment, are given in Table 1. Virtually all the root systems were distributed in the first 50 cm of soil. Most of the biomass was at depths more shallow than that. Means for the

nine species showed 39 percent in the first 10 cm, 70 percent in the first 20 cm, 86 percent in the first 30 cm, and 95 percent in the first 40 cm. This shallow rooting is related to the sparcity of precipitation [mean annual is about 10 cm (Beatley 1967, Wallace and Romney 1972)] and with the presence of a caliche layer at 30 to 50 cm. Phenology of the species concerned over a four-year period has been reported (Wallace and Romney 1972) as has the behavior of winter annuals in the area (Beatley 1967).

The portion of the root system in the first 10 cm of soil, though relatively large, was mostly in the form of multiple taproots. Further evidence of this was the small proportion of small roots to total roots in this zone (mean was 3.2 percent for eight of the nine species compared with 8.7 percent for the second 10 cm). Most of the small roots were in the 10 to 30 cm zone. It can be expected that high temperatures of soil surfaces, together with the fact that soil surfaces are drier than lower horizons, are responsible for this behavior. These two factors would account for the sparsity of small roots in the first 10 cm of soil.

There were species differences in root distribution. *Acamptopappus shockleyi* and *K.*

Table 1 continued.

<i>E. nevadensis</i> (7)	<i>A. dumosa</i> (8)	<i>K. parvifolia</i> (8)	<i>A. canescens</i> (6)	<i>A. confertifolia</i> (7)
(above 2 mm)				
38.4 ± 5.3	24.8 ± 2.4	39.9 ± 3.3	39.8 ± 5.0	39.7 ± 6.1
19.7 ± 3.6	25.7 ± 2.2	20.1 ± 5.2	14.9 ± 2.2	16.1 ± 1.5
11.2 ± 2.0	10.4 ± 1.7	2.1 ± 2.1	10.6 ± 2.5	6.7 ± 1.5
5.2 ± 1.8	4.0 ± 1.6	2.0 ± 2.0	4.9 ± 1.8	2.8 ± 0.6
1.0 ± 0.4	1.7 ± 1.2	0.0	6.0 ± 2.0	1.4 ± 0.6
0.0	0.0	0.0	1.4 ± 1.4	1.2 ± 1.2
(2 mm or less)				
1.6 ± 1.0	2.9 ± 0.7	16.3 ± 7.7	3.4 ± 1.1	6.1 ± 1.1
5.7 ± 1.1	9.9 ± 1.9	14.3 ± 3.3	10.7 ± 2.6	10.0 ± 3.0
10.6 ± 3.3	6.4 ± 1.6	2.9 ± 2.9	8.4 ± 1.4	7.4 ± 1.6
5.4 ± 2.2	4.4 ± 0.8	2.5 ± 2.5	4.9 ± 1.4	5.6 ± 1.5
1.1 ± 0.5	1.4 ± 0.9	0.0	4.5 ± 1.2	2.4 ± 0.9
0.0	0.0	0.0	1.1 ± 0.7	0.6 ± 0.6
24.6	24.4	36.0	33.0	32.1

TABLE 2. Root sampling in Rock Valley, 22 April 1976, in typical *Lycium pallidum* dominated area, using the pattern of Bamberg et al. (1974a).

	Inter-space (80%)	In canopy (13.3%)	Under plant (6.7%)	Total (100%)
kg/ha 0-10 cm				
Large roots*	—	—	—	—
Small roots	—	—	—	—
Fine roots	10	3	3	16
Fine roots in organic debris**	26	7	11	44
kg/ha 10-20 cm				
Large roots*	105	—	32	137
Small roots	54	—	3	57
Fine roots	30	11	11	52
Fine roots in organic debris**	68	7	22	97
kg/ha 20-30 cm				
Large roots*	143	14	7	164
Small roots	38	7	5	50
Fine roots	30	4	9	43
Fine roots in organic debris**	75	9	15	99
Totals	579	62	118	759
kg/ha totals by depth				
0-10 cm	36	10	14	60
10-20 cm	257	18	68	343
20-30 cm	286	34	36	356

*The large tap and main branching roots were not included in the sample.

**The maximum amount of the organic debris obtained with salt flotation that would be considered as roots was 35 percent, a value determined with ¹⁴C labeling (Wallace et al. 1980); value reported here takes that into account.

TABLE 3. Root sampling in Frenchman Flat, 22 April 1976, in typical *Ambrosia dumosa* dominated area, using the pattern of Bamberg et al. (1974a) (large roots not sampled).

	Inter-space (80%)	In canopy (13.3%)	Under plant (6.7%)	Total (100%)
kg/ha 0-10 cm				
Large roots (3 mm)*	—	—	—	—
Small roots (1 to 3 mm)	—	—	—	—
Fine roots (< 1mm)	—	—	—	—
Fine roots in organic debris**	15	3	32	51
kg/ha 10-20 cm				
Large roots*	—	—	—	—
Small roots	—	13	5	18
Fine roots	—	4	1	5
Fine roots in organic debris**	42	8	11	61
kg/ha 20-30 cm				
Large roots*	—	25	14	39
Small roots	—	5	2	6
Fine roots	18	17	1	36
Fine roots in organic debris**	17	15	3	35
Totals	92	90	69	251

*See Table 2.

**See Table 2.

parvifolia were more shallow rooted than other species. More than 85 percent of the root systems for these two species was in the first 20 cm. Lower stems of *K. parvifolia* were usually covered with about 10 cm of blow sand because of the catchment nature

of the shrub, so that roots actually were not as close to the surface as indicated. *Lycium andersonii* roots were more uniformly distributed throughout the root zone than most other species, although *L. pallidum* was somewhat similar. The two species that re-

TABLE 4. Root sampling in Mercury, 22 April 1976, in typical *Lycium andersonii* dominated area, using the pattern of Bamberg et al. (1974a).

	Inter-space (80%)	In canopy (13.3%)	Under plant (6.7%)	Total (100%)
kg/ha 0-10 cm				
Large roots*	—	—	21	21
Small roots	—	—	4	4
Fine roots	17	—	4	21
Fine roots in organic debris**	18	12	87	117
kg/ha 10-20 cm				
Large roots*	—	—	9	9
Small roots	—	—	7	7
Fine roots	51	2	7	60
Fine roots in organic debris**	84	5	48	137
kg/ha 20-30 cm				
Large roots*	—	25	457	482
Small roots	—	5	60	65
Fine roots	27	17	22	66
Fine roots in organic debris**	53	15	75	143
Totals	250	81	801	1132

*See Table 2.

**See Table 2.

main photosynthetically active longer in the season than others (*L. tridentata* and *K. parvifolia*) were not too much unlike other plants, except for the shallow nature of *K. parvifolia* mentioned above. *Krameria parvifolia* had a greater proportion of small roots than did other species.

Depth distribution of the very fine roots for Rock Valley was in kg/ha, 60, 149, and 142 for 0–10, 10–20, and 10–30 cm, respectively (Table 2). This was not different from roots in general. The surface soils of the northern Mojave Desert are low in both large and fine roots, and this probably is related to

high soil surface temperatures and low soil moisture of the summer months. This condition (few perennial roots in the surface 10 cm) does support a relatively large number of winter annuals after normal winter rainfall (Turner and McBrayer 1974).

Soil samples were also taken to measure primarily fine roots in Frenchman Flat and Mercury Valley by the procedures of Bamberg et al. (1974). These were not designed to collect the large and intermediate roots, although some appear in the samples (Tables 3 and 4). Indicated were 251 kg/ha for small and fine roots in the site in Frenchman Flat

TABLE 5. Depth distribution of roots from annual plants from different locations on the Nevada Test Site (collected 22 April 1976).

	100% of area, kg/ha			20% of area, kg/ha		
	Mercury	Frenchman Flat	Rock Valley	Mercury	Frenchman Flat	Rock Valley
0–5 cm depth						
Litter	870	367	—	—	—	—
Large roots*	—	—	—	—	—	38
Small roots	—	—	25	—	—	5
Fine roots	—	—	24	—	—	5
Fine roots in organic debris**	570	181	87	114	36	18
5–10 cm depth						
Large roots*	—	—	—	—	—	—
Small roots	—	—	20	—	—	4
Fine roots	145	5	27	29	1	5
Fine roots in organic debris**	242	31	76	38	5	15
10–20 cm depth						
Large roots*	183	—	181	37	—	36
Small roots	196	109	62	29	22	12
Fine roots	227	53	42	45	11	8
Fine roots in organic debris**	444	82	193	99	16	39
20–30 cm depth						
Large roots*	146	—	—	29	—	—
Small roots	185	—	—	37	—	15
Fine roots	163	25	77	33	5	9
Fine roots in organic debris**	511	104	228	101	21	46
Totals	3013	590	1278	602	118	255
Totals by depth						
0–5 cm	570	181	325	114	36	66
5–10 cm	387	36	123	77	7	24
10–20 cm	444	82	193	99	16	39
20–30 cm	1006	129	352	201	26	70

*See Table 2.

**See Table 2.

TABLE 6. Roots in soil samples collected in *Larrea-Ambrosia* communities on 24 September 1976. Values normalized 17 percent ash and corrected (organic debris corrected to 35 percent).

	Inter- space (80%)	In canopy (13.3%)	Under plant (6.7%)	Total (100%)
kg/ha 0-10 cm				
Large roots*	—	—	—	—
Small roots	—	—	19	19
Fine roots	25	19	8	52
Fine roots in organic debris**	19	18	81	118
kg/ha 10-20 cm				
Large roots*	—	—	—	—
Small roots	—	137	48	185
Fine roots	46	34	26	106
Fine roots in organic debris**	16	8	43	67
kg/ha 20-30 cm				
Large roots*	—	23	42	65
Small roots	—	25	46	71
Fine roots	25	12	12	49
Fine roots in organic debris**	15	5	45	65
Totals	146	281	370	797

*See Table 2.

**See Table 2.

TABLE 7. Root distribution in *Artemisia tridentata* on Pahute Mesa at the Nevada Test Site (organic debris corrected to 35 percent).

cm	Depth	Roots, kg/ha			Distribution for 5 cm increments
		Under	Canopy	Interspace	%
Big roots (over 3 mm)					
0-5	—	—	—	—	0.0
5-10	93	56	260	409	13.7
10-20	590	260	—	850	14.3
Small roots (1-3 mm)					
0-5	2	10	—	12	0.4
5-10	17	23	140	180	6.1
10-20	70	140	140	350	5.9
Fine roots (under 1 mm)					
0-5	21	10	—	31	1.0
5-10	32	47	77	156	5.2
10-20	78	77	98	253	4.3
Fine roots in organic debris*					
0-5	151	34	5	190	6.4
5-10	58	36	100	194	6.5
10-20	69	100	181	350	5.9
Totals					
0-5	174	54	5	233	7.8
5-10	200	162	577	939	31.6
10-20	807	577	419	1803	30.3
Total	1181	793	1001	2975	100.0

*See Table 2.

and 1132 kg/ha for the site in Mercury Valley. These samples were taken in spring, so they should have shown a component of fine roots due to phenological stage (Caldwell and Fernandez 1975).

Roots associated with winter annual plants are shown in Table 5. Two sets of values are shown. One is based on the assumption that the biomass is uniform and the other (realistic) is that the winter annuals occupy 20 percent of the land area. On this basis the estimated biomass in kg/ha for winter annual roots was 602, 118, and 255 for Mercury Valley, Frenchman Flat, and Rock Valley, respectively (22 April 1976).

The depth distribution of the annual roots was more shallow than for perennial plants, as expected. The first 5 cm of soil had 19, 31, and 26 percent, respectively, for Mercury Valley, Frenchman Flat, and Rock Valley. In the first 10 cm of soil from Rock Valley, only 8 percent of the perennial roots (mostly fine roots) (Table 2) were present. In Frenchman Flat and Mercury Valley they were 20 and 14 percent, respectively, but these values are for 10 cm and those for annuals were for 5 cm.

Another set of soil samples by the same procedure was taken on 24 September 1976 in a *L. tridentata*-*A. dumosa* community (Table 6). The total root biomass in kg/ha was 797 at this September date, which is essentially the same as the April date in Table 2 (759 kg/ha).

To compare the root patterns of the first 5 cm of soil of the Great Basin desert (an *Artemisia* community) with the northern Mojave Desert, a root sampling procedure as above was used in Pahute Mesa (Table 7) of the Nevada Test Site. The percentage of the roots in the first 5 cm was 7.8 percent, which is about the same as in the first 10 cm of the northern Mojave Desert. In the first 10 cm at Pahute Mesa, 39 percent of the roots were present. Solid rock existing below 20 cm at the site sampled prevented root distribution at lower depths. The root sample of 2975 kg/ha com-

pares with an estimated aboveground biomass of about 3000 kg/ha (Wallace and Romney 1972).

ACKNOWLEDGMENTS

This study was supported by U.S. International Desert Biome and Contract EY-76-C-03-0012 between the U.S. Department of Energy and the University of California.

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